Fermi National Accelerator Laboratory

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Impedance Issue of Corrugated Beam Pipe from CDF

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I. INTRODUCTION

The CDF collaboration proposed to instal a new corrugated beam pipe at the Tevatron interaction area in order to better monitor the interaction vertex. This note discuss the impedance implication of such a pipe. The drawings of the corrugated pipe are shown in Figs. 1 to 3.

II. CRUDE ESTIMATION

This beam pipe has a radius of $b = 2$ in and of length 128 in only. It therefore will neither influence in any way the resistive-wall impedance of the whole vacuum chamber, nor will it change the space-charge impedance. As a result, the only features that we need to consider are the roughly $N = 222$ corrugations or convolutions, which have a depth of $d - b = 0.546$ cm and a width of $g = 0.183$ cm. Because these convolutions are separated from each other by 1.463 cm, it is not a bad idea to assume that they do not talk to each other. At low frequencies, the longitudinal impedance per unit harmonic is given by

$$\frac{Z_\parallel}{n} = j\alpha\beta Z_0 \ln\frac{d}{b} , \tag{2.1}$$

where βc is the velocity of the beam particles, $Z_0 = 377\ \Omega$ is the free-space impedance, and α is the fraction of the ring with the corrugations; therefore

$$\alpha = \frac{Ng}{2\pi R} \tag{2.2}$$

where $R = 1$ km is the ring radius. Putting in the numbers, we get

$$\frac{Z_\parallel}{n} = j0.0047\ \Omega , \tag{2.3}$$

which should be correct when $n \ll \alpha^{-1}$, or $\ll 0.74$ GHz. For higher frequencies, we will meet with resonances inside the convolutions. An estimation is that the depth of the convolution $d-b = 0.546$ cm will sustain a quarter wavelength. Therefore, the lowest resonant frequency is $f \sim c/4(d-b) = 14$ GHz. Since this is well above cutoff, we expect the resonance to be quite wide.

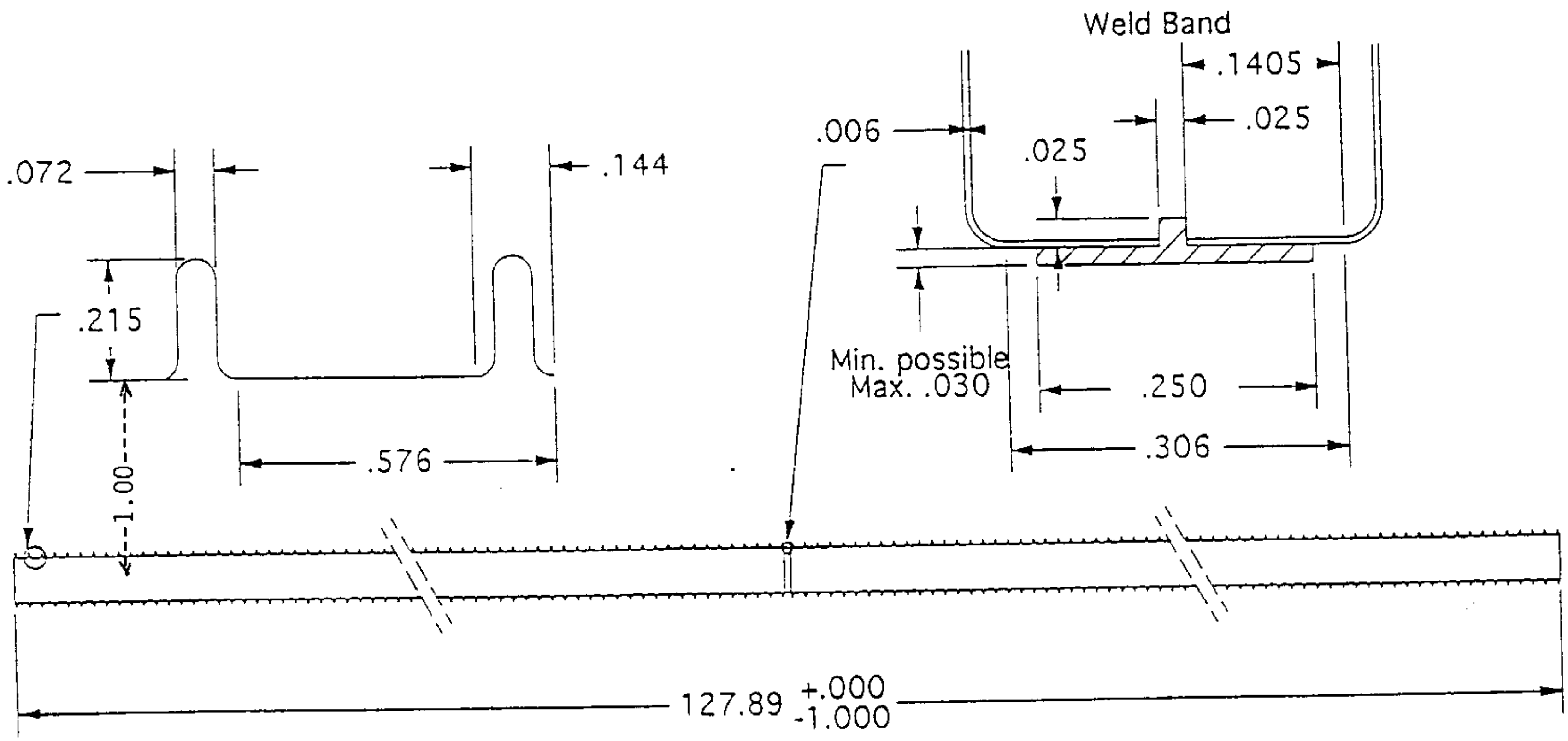
III. TBCI

TBCI was run for a portion of the beam pipe containing 10 convolutions. The longitudinal impedance is shown in Figs. 4 and 5. We do see a resonance at $\sim$ 10 GHz. For a total of 222 convolutions, we have at low frequencies $Z_{\|}/n = j0.0045\ \Omega$ (at least up to 5GHz). The lowest resonance has a width of $\sim$ 6 GHz. The maximum shunt impedance is $\sim$ 11 kΩ if the contribution of all convolutions adds constructively; however, this corresponds to a Z/n of 0.05 Ω only.

The transverse impedance from TBCI is shown in Figs. 6 and 7. At low frequencies, $Z_{\perp} = j12.9$ kΩ/m for all the convolutions of the beam pipe. The first resonance is again at roughly 10 GHz with a width of $\sim$ 6 GHz. The total maximum shunt impedance is 104 KΩ/m if all convolutions add constructively.

IV. CONCLUSION

The longitudinal and transverse impedances of the corrugated beam pipe turn out to be quite small ($Z_{\|}/n \ll 1\ \Omega$ and $Z_{\perp} \ll 1$ MΩ/m) both at low frequencies and at the peak of a resonance. As a result, the installation of this pipe will not lead to any instability of the beam.



Bellows:
Material: Stainless Steel $\sigma = 0.135\times10^{7}\ (\Omega m)^{-1}$
O.D. = 2.43
I.D. = 2.0
Pitch of one convolution = 0.144
Pitch of skipping 3 between each conv. = 0.576
Wall = 0.006
# of Sections = 2
End connections accomplished by weld bands made as small and thin as possible, max. thick. = 0.016
Mass Spec. checked to leak rate of < 1.0 E-9 cc/sec
Must be able to withstand pressure internally and externally of up to twice atmospheric.
All dimensions in inches.

Figure 1

DRAWN BY: JEFF MUSUR		DATE: 9/3/92	
APPROVED BY:		DATE:	
FERMI NATIONAL ACCELERATOR LABORATORY, UNITED STATES DEPARTMENT OF ENERGY			
BELLOWS TRANS. SPOOL DESIGN			
SCALE: NONE	DRAWING NO.:		REV: A

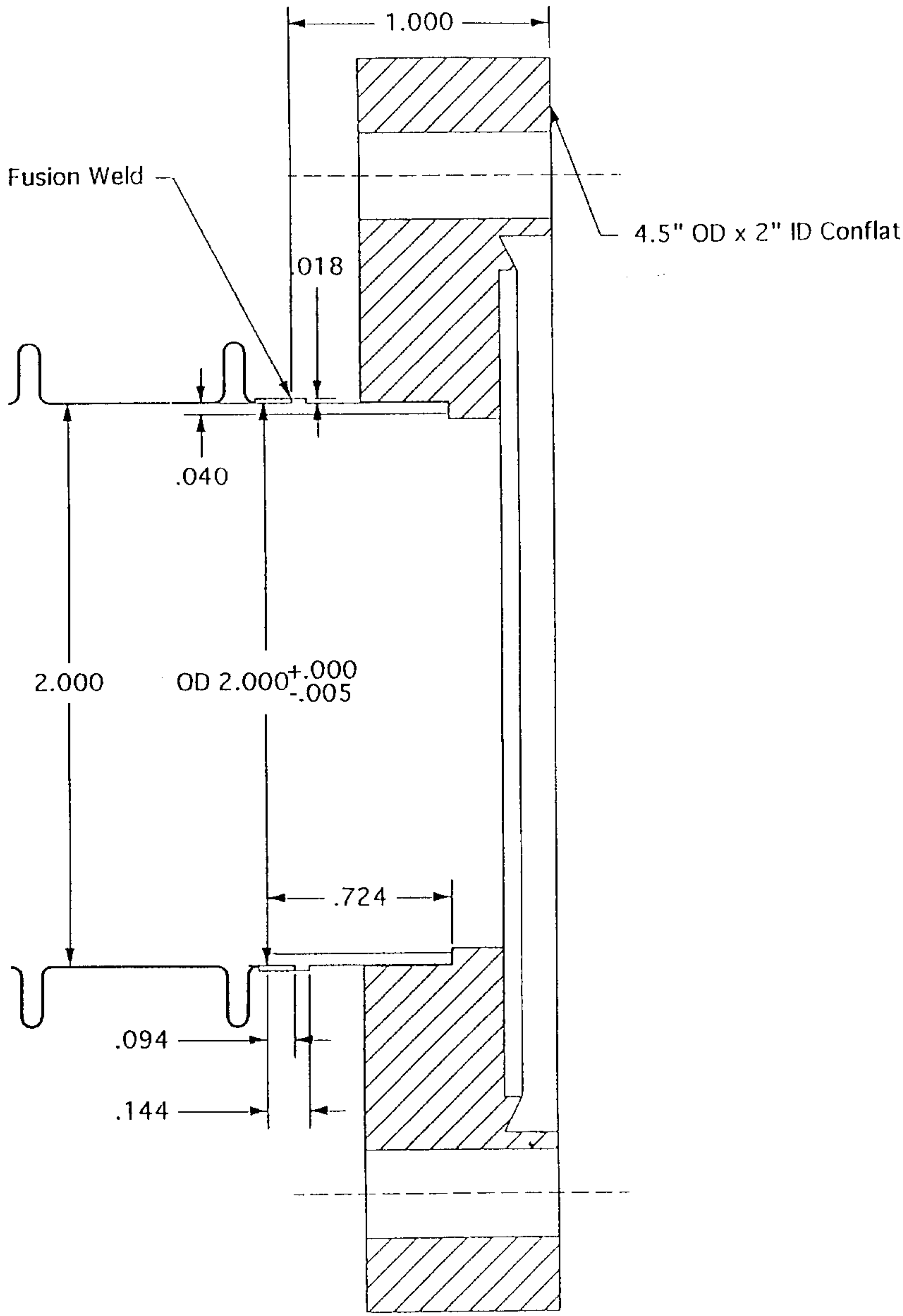
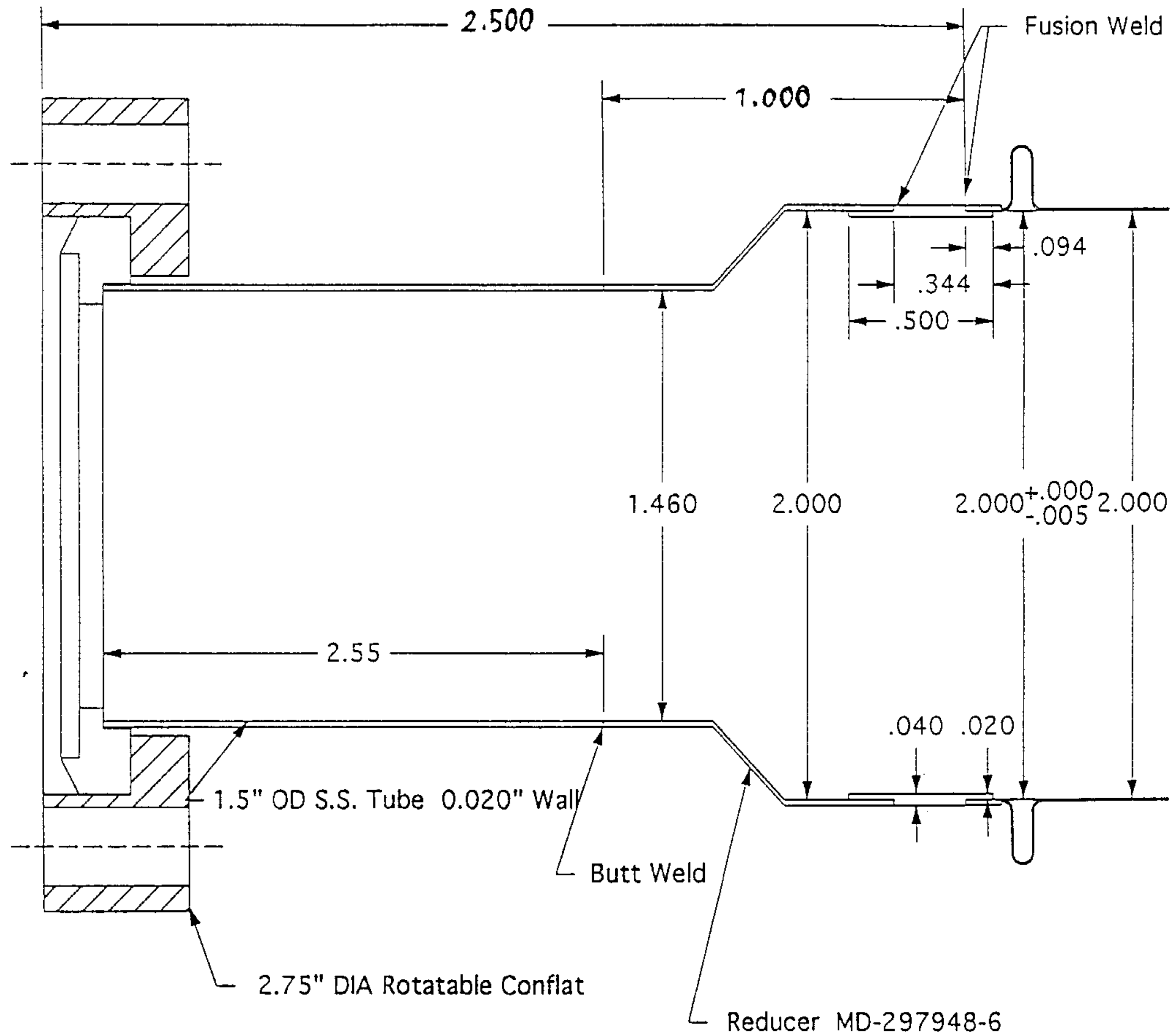

1.000
Fusion Weld
4.5" OD x 2" ID Conflat
.018
.040
2.000
OD 2.000 +.000 -.005
.724
.094
.144

Figure 2



2.500
Fusion Weld
1.000
.094
.344
.500
1.460
2.000
2.000 +.000 -.005
2.000
2.55
.040
.020
1.5" OD S.S. Tube 0.020" Wall
Butt Weld
2.75" DIA Rotatable Conflat
Reducer MD-297948-6

Figure 3

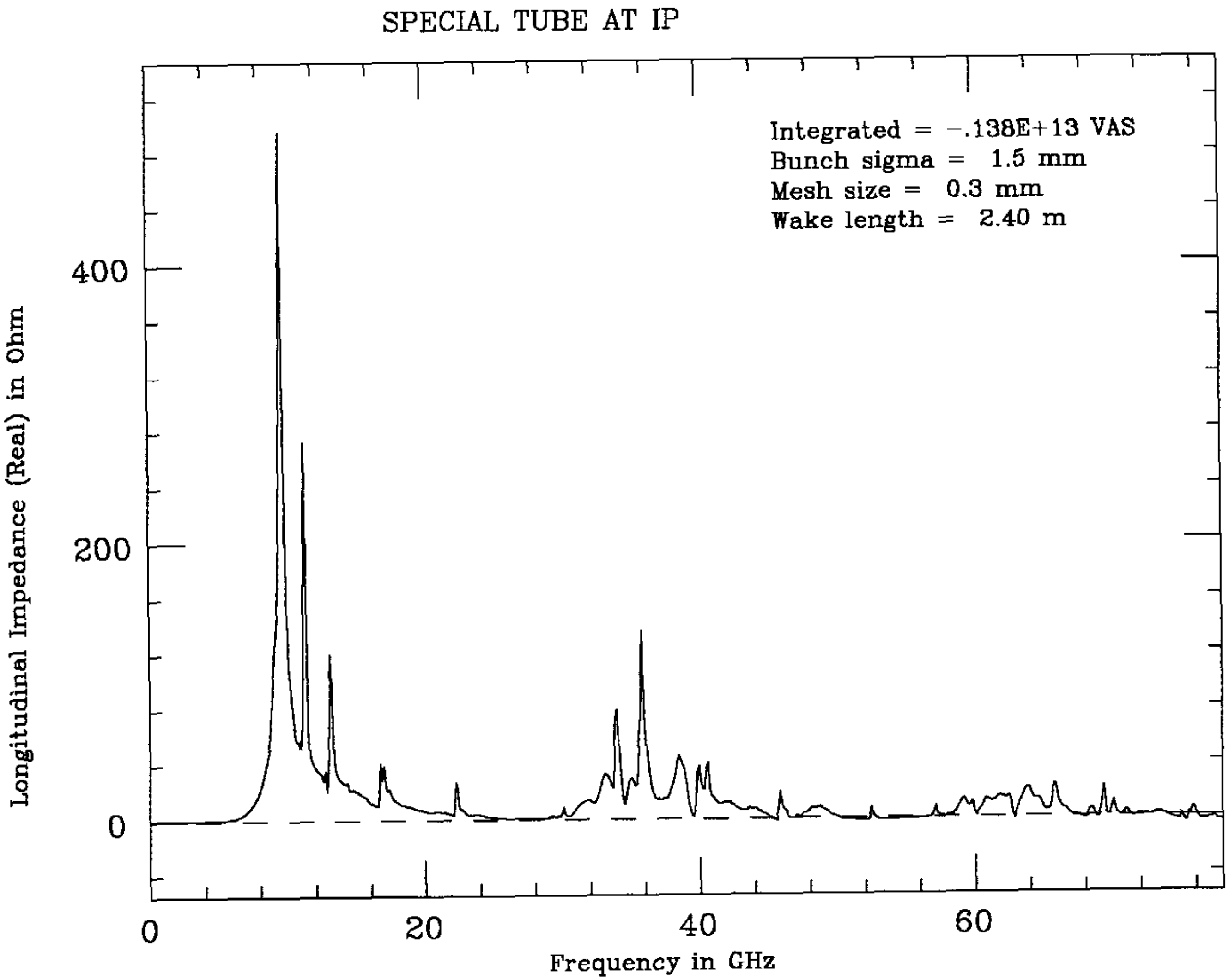

SPECIAL TUBE AT IP
Integrated = −.138E+13 VAS
Bunch sigma = 1.5 mm
Mesh size = 0.3 mm
Wake length = 2.40 m
400
200
0
Longitudinal Impedance (Real) in Ohm
0
20
40
60
Frequency in GHz

Figure 4

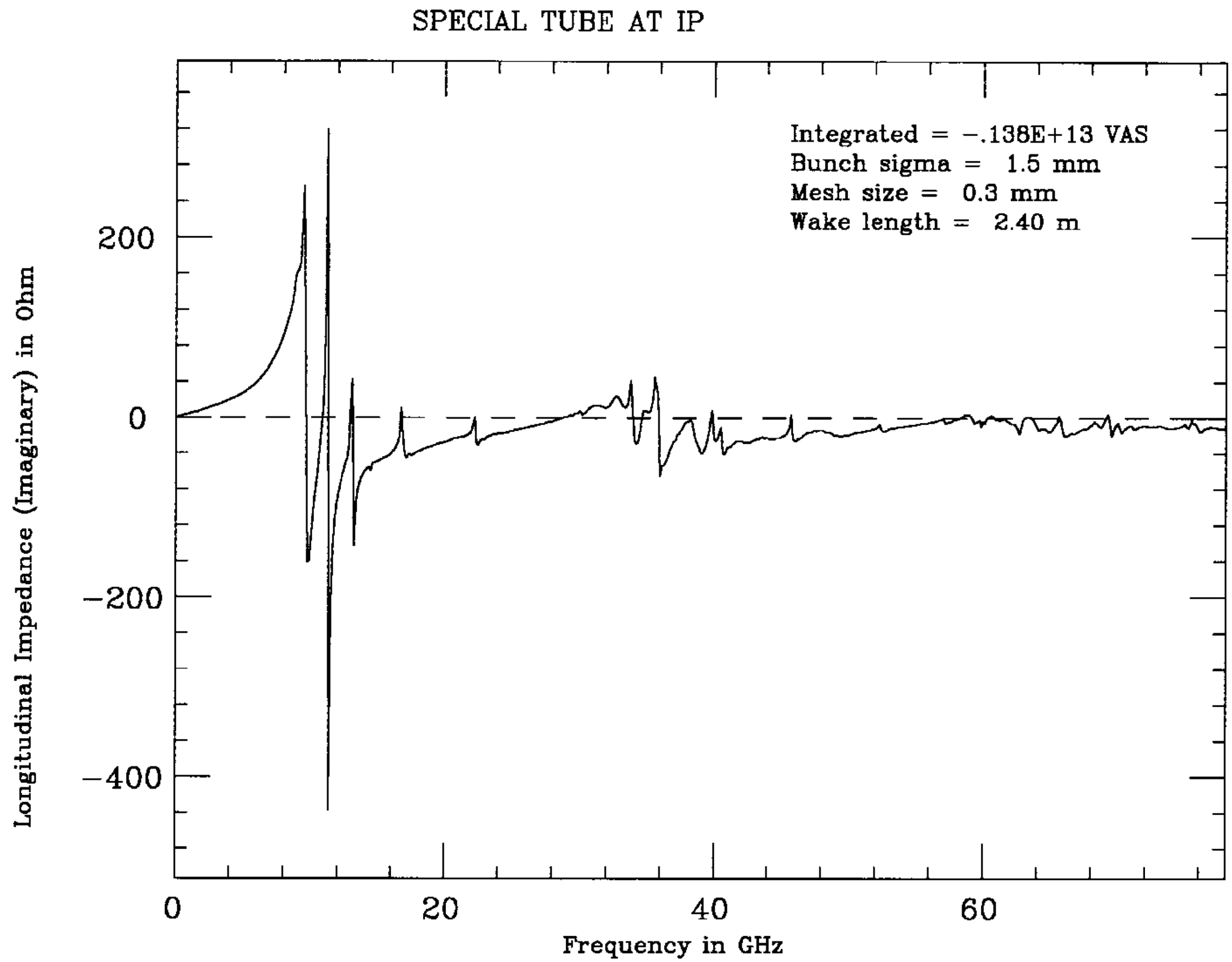

SPECIAL TUBE AT IP
Integrated = −.138E+13 VAS
Bunch sigma = 1.5 mm
Mesh size = 0.3 mm
Wake length = 2.40 m
200
0
−200
−400
Longitudinal Impedance (Imaginary) in Ohm
0
20
40
60
Frequency in GHz

Figure 5

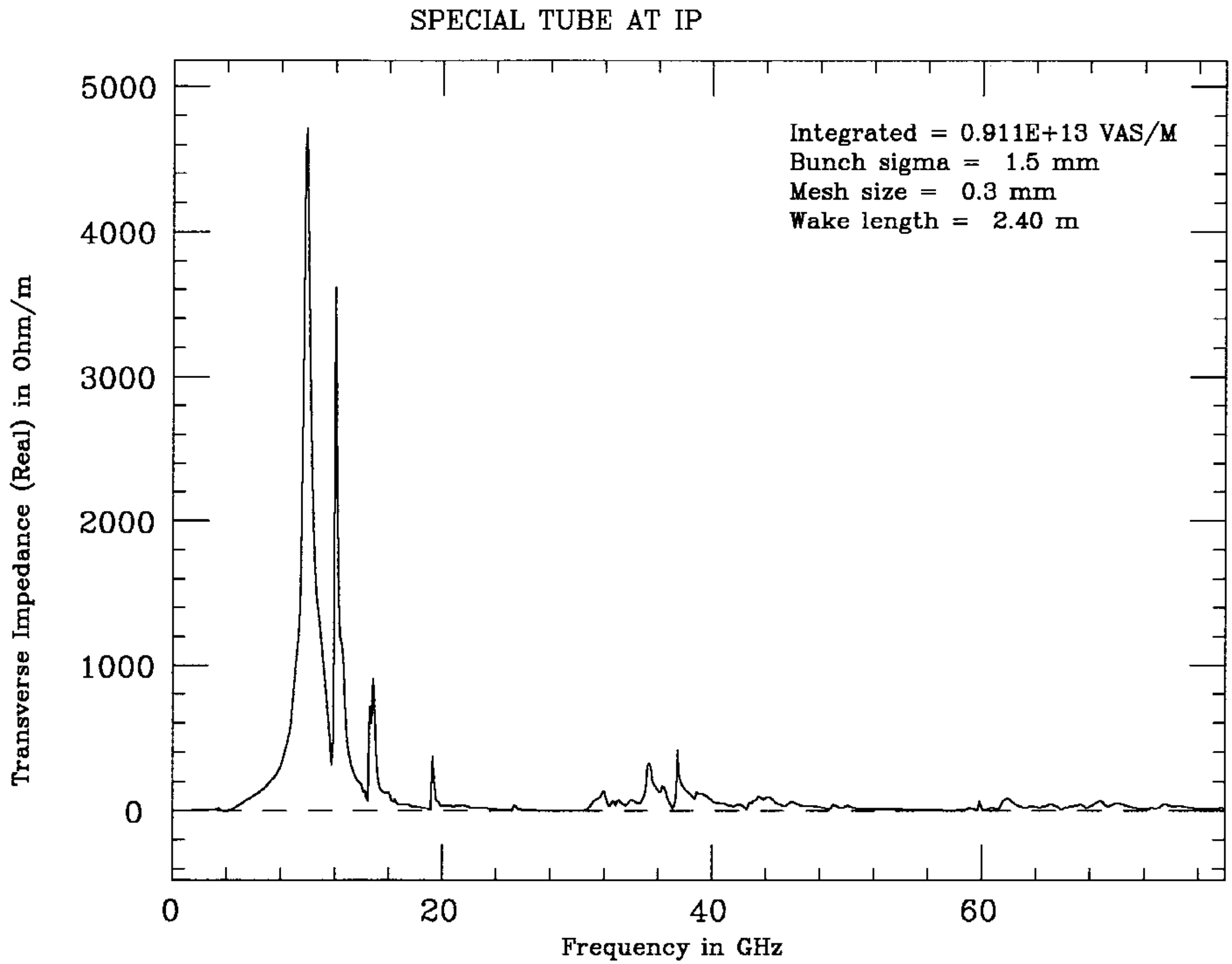

SPECIAL TUBE AT IP
Integrated = 0.911E+13 VAS/M
Bunch sigma = 1.5 mm
Mesh size = 0.3 mm
Wake length = 2.40 m
Transverse Impedance (Real) in Ohm/m
Frequency in GHz
5000
4000
3000
2000
1000
0
0
20
40
60

Figure 6

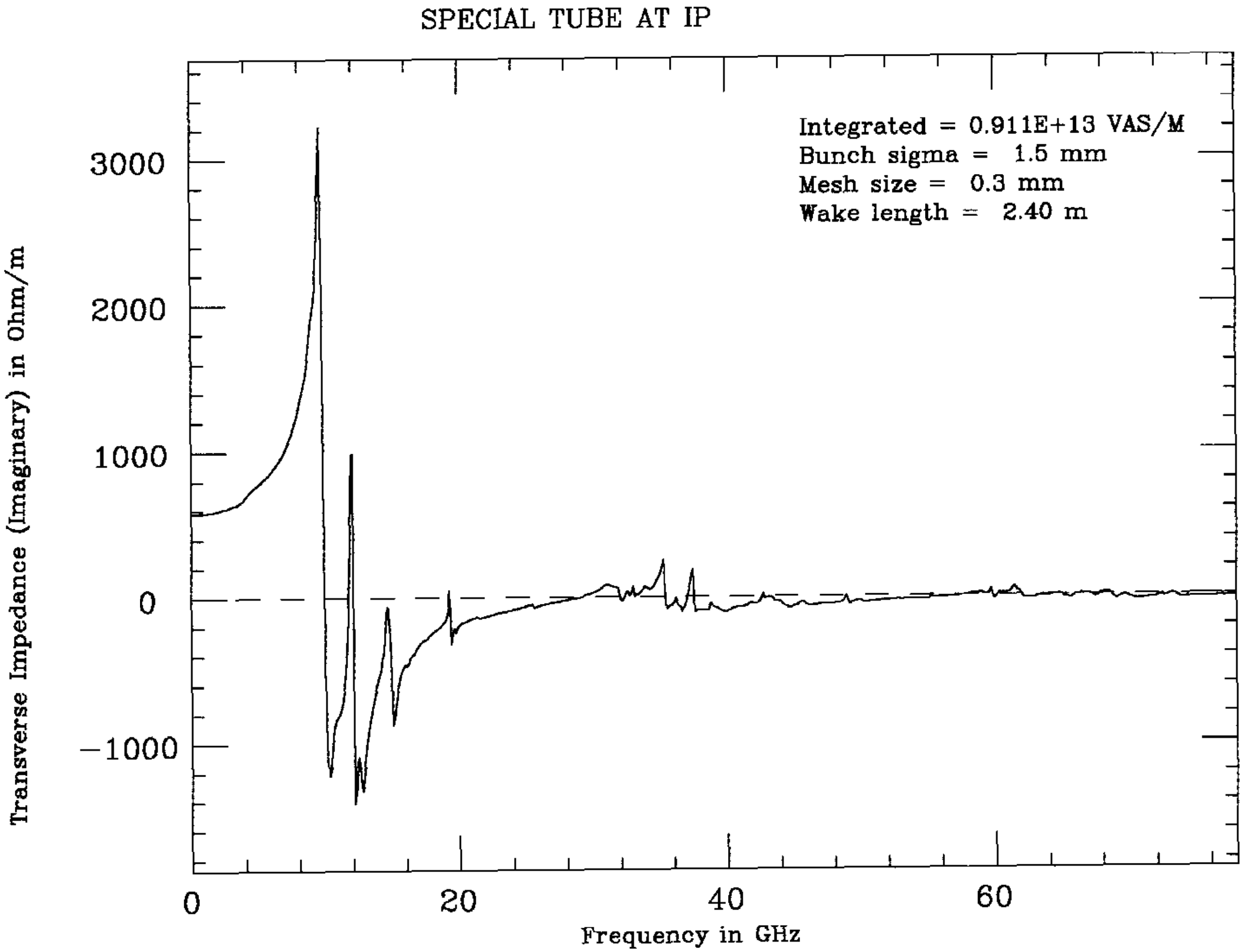

SPECIAL TUBE AT IP
Integrated = 0.911E+13 VAS/M
Bunch sigma = 1.5 mm
Mesh size = 0.3 mm
Wake length = 2.40 m
3000
2000
1000
0
−1000
Transverse Impedance (Imaginary) in Ohm/m
0
20
40
60
Frequency in GHz

Figure 7